VENTILATION SYSTEMS AND INTERACTIONS WITH CONTROL ROOM HABITABILITY

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Abstract

Control Room Habitability (CRH) is the term used to describe the analysis and the systems and structures used to protect commercial nuclear power plant Operators and control room equipment; plus provide a safe environment during normal and accident conditions. Over the past 40 years in the United States this concept (i.e., CRH) has evolved tremendously from that of protecting Operators from the effects of an accidental radiation release to providing a control room that can be occupied 24 hours a day during all manners of events; both natural and man made. During the past 40 years the effects of the ventilation system on CRH has not always been fully understood or only understood by a few individuals. This is compounded by the practice of many in the commercial power production industry as considering the CRH (and associated HVAC) a low priority system. Additionally, there have been numerous documented instances where the CRH ventilation systems have been given little maintenance resulting in degradation of the CRH boundary to such an extent that the existing analysis could not support the actual plant configuration. The CRH issues received new interest in 1998 when the Nuclear Regulatory Commision (NRC), Nuclear Energy Institue (NEI), and Nuclear HVAC Utilities Issues Group (NHUG) held a CRH workshop in Washington, D. C. This workshop presented the issues facing the industry in all facets of CRH. Chief among the facets were the ventilation systems serving the CRH boundary. Following the workshop the NEI formed a TF to address CRH. This TF is currently working directly with the NRC to develop a voluntary document that can be used to assess CRH. This paper presents the issues specific to the ventilation systems as they now appear in the development of NEI 99-03, "Control Room Habitability Assessment Guidance," and how these systems interact and affect CRH. It also discusses the resolution of issues pertinent to ventilation systems and CRH and proposes what is considered a good design for a CRH ventilation system.

Background

CRH has been with the commercial nuclear industry since its inception. Available published information on CRH dates from the 1960's and forms the foundation upon which all later work was produced. In order to help understand why CRH is still be discussed we must know how the CRH requirements evolved [5]. The following provides a brief overview of the control room habitability regulatory and licensing history:

- 1967 Draft AEC GDC 11 established requirements for control room habitability prior to GDC 19
- The 1969 Atomic Industrial Forum (AIF) GDC 11 further iterated these same requirements for control room habitability prior to GDC 19.
- In 1971, 10 CFR 50 Appendix A, General Design Criterion 19 (GDC 19) required protection of the operators.
- Early 1970's, Murphy and Campe presented a method for evaluating control rooms for a radiological event.
- In 1974 and 1975, Regulatory Guides 1.78 (toxic gas) and 1.95 (chlorine) were issued to provide guidance to the industry concerning toxic gas.
- Following the Three Mile Island (TMI) accident, actions were mandated (NUREG 0660, May 1980).

Additionally, NUREG 0737 TMI action item III.D.3.4 clarified the licensee evaluation of control rooms to assure adequate protection of operators.

- In 1985, NRC issued a report on the capabilities of control rooms (based on a review of three plants). The survey concluded (in part) that configuration control was a problem and that NRC documents (Regulatory Guides, lack of criteria, and Standard Technical Specifications) were inadequate. It also recommended additional reviews to confirm the findings. A follow-up report issued in 1988 supports previous guidance recommending improvements in NRC requirements.

- In 1986, NRC held meetings and issued Information Notices concerning inadequacies of control room designs in assuring control room habitability requirements are met.

- Between 1980 and December 1996, numerous documents were published to assist the industry in evaluating control rooms for effects of toxic gas and radiation. These documents provide direction and computer codes to assist in analyzing, calculating, and evaluating effects of toxic gases on control room operators. NUREG/CR-6210, issued in June 1996 was the culmination of these efforts and combined all previous guidance into one document.

- In 1998, NRC held a public workshop to express concerns similar to those from 1986.

As the dates of nuclear power plant construction and operation varied throughout the evolution of CRH; many plants in the US have varying designs and commitments to regulations which are too numerous to describe here. CRH was initially concerned with the protection of Operators from the effects of radiation and by so doing allow Operators to protect the public by mitigating effects of an accident. As can be seen in the above timeline other items such as toxic gas considerations, operation, and maintenance became issues with CRH.

There have been numerous papers published concerning the design for CRH and of ventilation systems serving the CRH boundary (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17). These references provide the foundation from which a CRH system can be design and constructed. The basic concepts in all of the issued guidance for CRH is that intrusion of radiation and toxic gases into the CRH boundary must be prevented and/or limited. The three designs that are typically used for accomplishing this feat are (16):

- Zone isolation, with the incoming air filtered and a positive pressure maintained by the ventilation system fans. Figure 1
- Zone isolation, with filtered recirculated air. Figure 2
- Zone isolation, with filtered recirculated air, and with a positive pressure maintained in the zone. Figure 3

Additionally the following can also be added to the above basic designs:

- Dual air inlets for the emergency zone should be provided. Two widely spaced inlets are located outboard, on opposite sides of potential toxic and radioactive gas sources. The arrangement helps assure at least one inlet being free of contamination. It can be used in all types of plants.
- Makeup- air supplied from the contamination-free inlet provides a positive pressure in the emergency zone and thus minimizes infiltration. Bottled air supply for a limited time.

In the 1980's there were numerous NRC reviews were conducted at US nuclear power plants and also to review CRH requirements (2,3,6,7,11). These reviews revealed deficiencies in the CRH systems. Examples of these deficiencies were in the area of technical specifications, boundary maintenance, knowledge of station personnel concerning CRH, treatment of CRH as a low priority item, and testing of the boundary. These items were communicated to the industry via NRC Information Notices and forums such as the Nuclear Air Cleaning and Treatment Conference. In the mid 1990's application of tracer gas techniques were used to determine actual unfiltered inleakage at various plants (figure 4). The accuracy of this methodology though has not been accepted by all in the industry. The test protocols were developed from ASTM Standard E741 (18) and used at various power plants around the US (19, 20 ,21). Notably all plants did not meet their unfiltered inleakage assumptions (22). The conclusion from the efforts in testing was that even the best <u>analyzed</u> plants may not perform well due to problems in the ventilation systems that were not foreseen by the designers. This would result in exposures to significantly higher that predicted dose and/or exposure to toxic

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substances.

Typical Pressurized Control Room HVAC

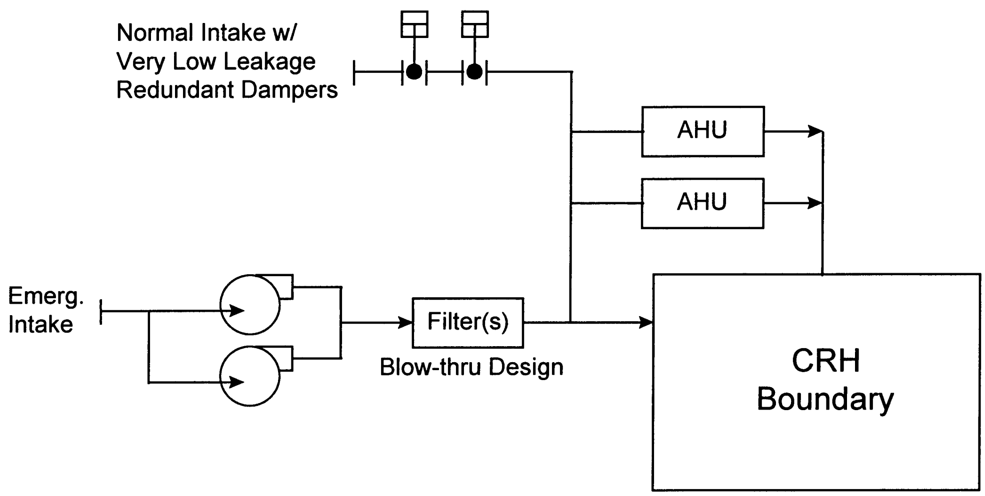

Figure 1

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Typical Recirculation Control Room HVAC System

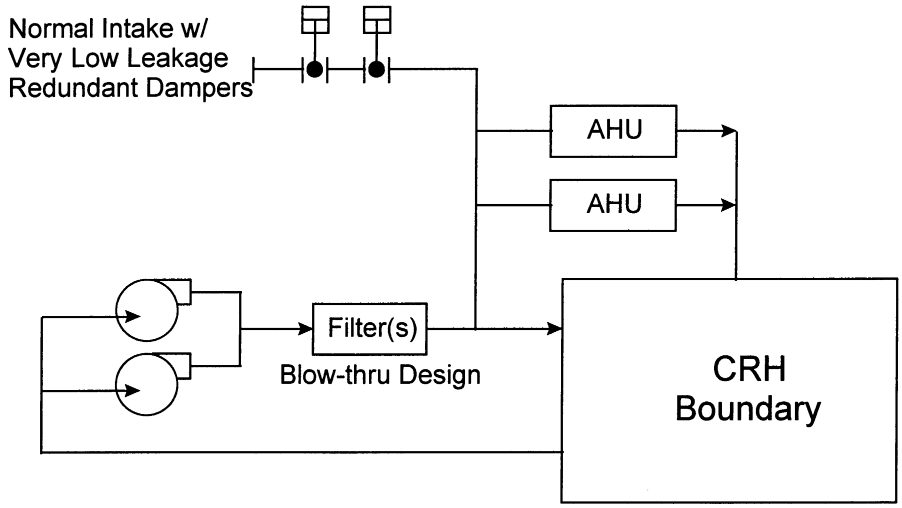

Figure 2

Typical Pressurized & Recirculation Control Room HVAC System

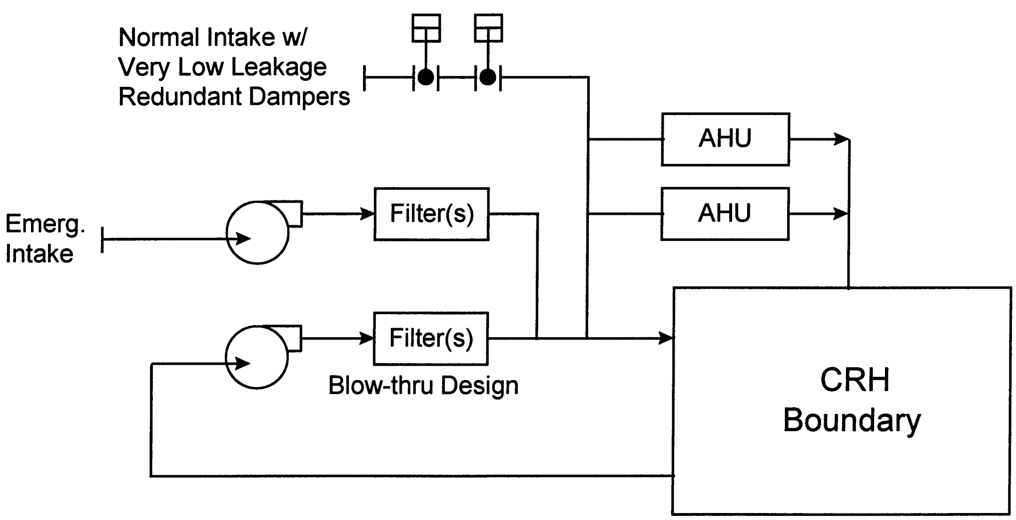

Figure 3

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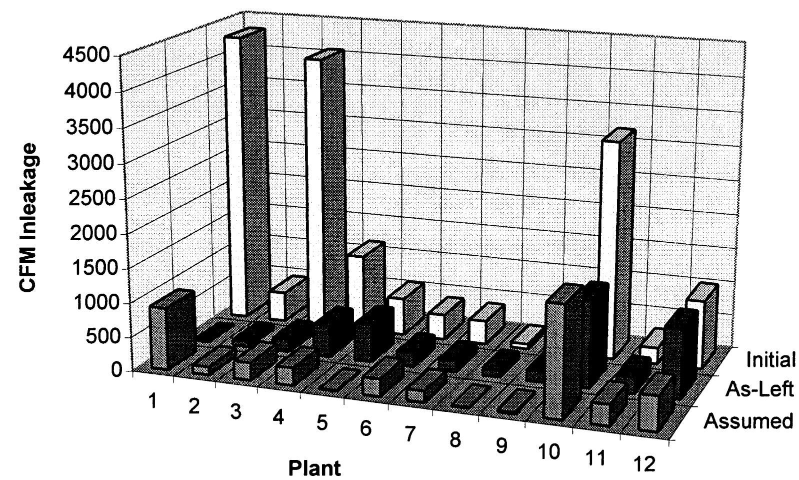
Control Room Inleakage Assumed, Final Measured, and Initial Measurement - Figure 4



Notes for figure 4:

a. Plant 1 was in the process of sealing penetrations and had not performed a final test at the time of this data point.
b. Pants 4, 5, 8, 9, 12 all re-performed or were in the process of re-performing analysis to accept their final measured inleakage. This was done by reevaluating assumptions in the analysis.
c. Assumed values are based on highly conservative calculations

Discussion of NEI Effort

The net result of all this testing and information was the indication that the industry was not performing well in the area of CRH which resulted in the formation of an Nuclear Energy Institute (NEI) CRH Task force (TF). The TF is developing a comprehensive assessment guidance document for the industry to use in assessing, testing, and maintaining CRH systems [23]. The TF is working directly with the NRC to develop this document. An essential element of this effort is the physical aspects (i.e., the ventilation systems) of CRH. The HVAC systems aspects of the NEI effort is concentrated in several appendices to the document. These appendices are:

- App I, SYSTEM ASESSMENT
- App J, TESTING OPTIONS
- App K, CONTROL ROOM ENVELOPE MAINTENANCE
- App L, CONTROL ROOM ENVELOPE INTEGRITY PROGRAM

The four appendices, if followed, would reduce the impact of the physical aspects of the HVAC system design and of the leakage through doors and other penetrations upon the basis for the CRH design. This is primarily to reduce leakage (unfiltered leakage for radiation and inleakage for toxic gas). The reduction of this leakage results in reduction of radiation exposure and exposure to toxic chemicals for the operators during periods when the control room must remain habitable.

Appendix I provides guidance for walkdowns and inspections to identify potential vulnerabilities to leakage. Its intended purpose is to identify potential vulnerabilities to inleakage. The appendix provides for a walkdown methodology which includes these following elements:

- Identify the boundary
- Identify operating configurations
- Performing the walkdown

Specifics of the appendix Includes

- Visual examination, differential pressure and system flow measurements
- Boundary penetrations, doors, isolation dampers inspections
- Determination of effects of other systems in the envelope
- Review of the general boundary construction

Appendix J provides guidance on the development of a testing program. It is of the opinion of the NEI CRH TF that a baseline test of the CRH boundary must be performed if a utility decides to assess their CRH using NEI 99-03. This baseline test does not imply that a tracer gas test is the only method to determine inleakage; it just indicates that a test is needed to actually determine a value. The appendix provides guidance in how to choose an appropriate test. Guidance in the appendix includes information for utilities in preparing for an integrated tracer gas test. This particular appendix is intended to aid plant personnel in the development of a plant specific procedure for testing. Prior to performing/developing any testing/testing program certain prerequisites are required.

- Assessment per Appendix I
- Any sealing/refurbishment/repairs
- Should have contingency plans
- Rebalance the HVAC system

Following completion of the prerequisites a determination of system mode of operation for testing is required. The mode of operation could be for accident (radiological concerns) and/or toxic gas mode. The testing in the operating modes includes integrated tracer gas testing, component testing, and/or alternate test methods. Finally a determination of the need to periodically verify the inleakage value must be made.

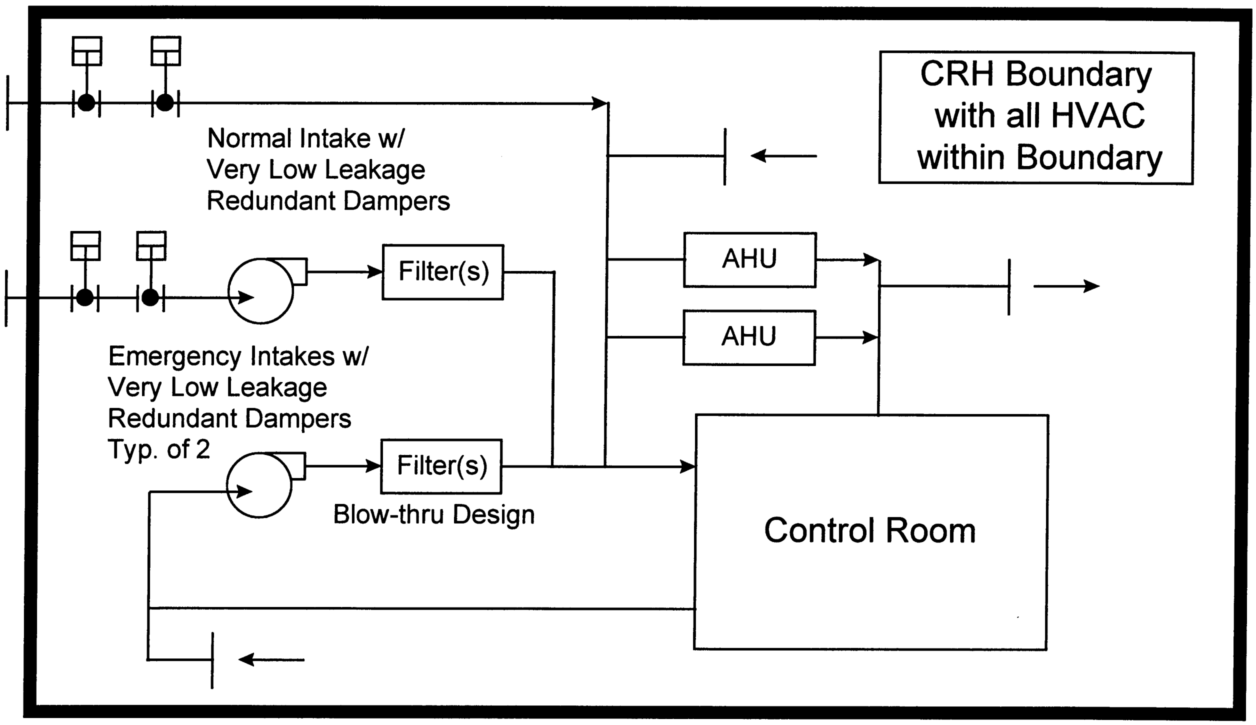
Appendix K provides guidance on the maintenance of the CRH boundary. The information within this appendix assures that the CRH boundary design and licensing bases determined in the assessment process will be continued to be met and maintained. This appendix covers the following areas:

- Doors and door seals
- Isolation dampers / shafts and gaps
- Fire Dampers
- Gaps (required for fire damper thermal expansion) around Fire Dampers
- CRH boundary walls/ceilings/floors and Gaps at building intersections
- Ducting traversing the CRH boundary and at higher pressure
- CR pressure boundary ducting outside CRH boundary
- Duct penetrations

Appendix L provides guidance on administrative requirements, responsibilities, and control for breaching the CRH boundary. This appendix may be used by plant personnel to develop a plant specific procedure controlling CRH boundary breaches. It also defines the expectations for a Control Room Envelope Integrity Program that provides reasonable assurance that CRE integrity is maintained throughout the life of the plant. Boundary control encompasses such things as opening and closing doors, sealing and opening and sealing back penetrations, monitoring control room pressures, etc. Each plant must tailor its program to the system/building configuration, accident analysis and plant procedures, but a program should be in place. The essential elements of an integrity program is to assure that a breach is evaluated properly, implemented under a controlled program, monitored while in place, returned to normal configuration, closed properly (including storage of documentation). A tracking mechanism to assure that the preceding elements are adhered to along with defined responsibilities for breaching are necessary for the program. This appendix requires that Appendix K be followed for the maintenance of the CRE.

Conclusion

Results of the NEI effort, along with the previously published information, will result in improvements in CRH and the increased assurance that Operators will be protected during all modes of plant operation. It would do this by establishing that the CRH boundary (and HVAC) are performing as required (i.e., minimize leakage across the boundary) and putting in place programs assuring that the boundary and HVAC will not degrade. Other improvements will be the increased knowledge levels of station personnel, increased emphasis on maintenance, and a program to insure that the boundary integrity is maintained. Additionally, the NEI TF efforts have indicated that the best design for the CRH HVAC systems would have all HVAC within the boundary (see Figure 5 for an example) and have a pressurized boundary. This would also include dual emergency air intakes.



Preferred Pressurized & Recirculation Control Room HVAC System
Figure 5

(One train of a typical two train system shown)

Acknowledgments

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